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Indoor assessment of dust drift effect from different types of pneumatic seed drills

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Abstract

The air stream generated by the fan of pneumatic seeders – necessary to create a depression in the sowing element of the machine and to guarantee correct seed deposition – can blow away solid particles that have been detached from the seeds. In this study, experimental tests were carried out to evaluate the performance of technical solutions by seeder producers to limit dust drift. A specific test methodology has been developed to assess sowing machine performance.

The tested technologies that convey the air to the soil, independent of their design, resulted in seed particle drift to be reduced by more than 60% compared to a conventional machine with the fan outlet oriented upwards. Particle drift was reduced by more than 70% if only an area between 5 and 20 m downwind the machine border was considered. This study has shown that the use of an appropriate design can reduce the dispersion of toxic substances in the atmosphere during seeding and that the methodology developed to carry out the trials could be used for seeder dust dispersion classification.

Keywords: pneumatic seed drills, neonicotinoides, maize seed, dust drift

Introduction

Dust dispersion from the seed drills during the sowing of pesticide treated seeds is considered an important environmental problem. In fact, when pneumatic seeders are used to apply neonicotinoides insecticide dressed maize seeds, a dispersion of solid particles containing the insecticides may be generated in the areas surrounding the seeded fields (Heibach et al., 2013; Dechet et al., 2013; Baldessari et al., 2009; Greatti et al., 2006; Altmann, 2003; Schnier et al., 2003; Greatti et al., 2003). All the seed drills produce a fine dust due to the abrasions of the seed coating that occurs inside the seeding element (Foqué et al., 2013). The air stream generated by the fan of pneumatic seeders – necessary to create a depression in the sowing element of the machine and to guarantee a correct seed deposition – can blow away the solid particles detached from the seeds (Balsari et al., 2010; Balsari et al., 2013).

During the last years, Research stations have found different solutions to classify the seed drill in function of "dust dispersion" in the atmosphere. One method used to determine the dust quantity emitted from seed drills fan is that typically used for agricultural sprayers (Rautmann et al., 2009). This method is described in the ISO 22866 standard and foresees to carry out the trials in the field, operating with constant wind speed (at least 1 m s^{-1}) and constant wind direction (transverse to the seeder's forward direction) and simulating the seeding operation on a surface of 1 ha. These environmental conditions requirements, however, are very difficult to be met and many times the tests requires several days of work with consequent high costs.

Another method used consists of inserting the seed drill in a wind tunnel to simulate the seeding operation. In this case the wind is produced by a fan and the dust is collected by positioning the Petri dishes at different distances downwind the machine (Biocca et al., 2011). This method, however, also shows some problems because the seeding elements are not inserted in the soil as it happens in the field and this could increase the possibility of dust drift. Furthermore, with this method it is necessary to use dressed seed, which is dangerous for operators.

The present study was therefore set up to develop a new experimental method aimed at assessing dust drift from maize seeders, overcoming the problems encountered applying the test methods described above.

2. Materials and methods

2.1. Tests made

Tests were conducted in order to assess the dust dispersion from different pneumatic seed drills. For each sowing machine tested, the amount of dust deposit at different downwind distances from the seed drill was determined using a specific developed methodology.

2.2. The developed methodology

The methodology set up consists in simulating in a wind tunnel the environmental air stream produced by an axial fan and downwind collection of the tracer emitted from the seeder's fan outlet. A specific dust yellow tracer (Tartrazine E 102) was used in the trials because it showed physical characteristics similar to those of the dust dispersed by the fan of pneumatic seed drills operating with dressed seeds (Table 1).

Use of this tracer allowed tests to be done in indoor conditions without specific precautions.

The tunnel, 5 m wide, 3 m high and 50 m long, was made with a modular iron structure covered with nylon film (Fig. 1). At one side of the tunnel an axial fan of 490 mm diameter and with 9 blades inclined at 50° was positioned. The air stream generated by the fan struck from one side the seeder that was positioned in the middle of the tunnel. Tracer dust deposits were then collected on Petri dishes placed on the ground at different downwind distances from the machine.
In order to guarantee a uniform air stream, in all the tunnel areas close to seeders tested, the machines were always positioned at 22 m distance from the axial fan outlet.

Inside the tunnel, downwind from the seeder position, arrays of 5 artificial collectors (Petri Dishes, 138 mm diameter) were placed on the ground at distances of 1, 3, 5, 15 and 20 m from the downwind edge of the machine. In each array, Petri dishes were placed at 1 m spacing (Fig. 1).
Tests were conducted using the sowing machines with seeds in their hoppers and, after filling, the disc of the seeding element, adopting the fan revolution speed recommended by the manufacturer and employing 4 or 6 seeding elements, was inserted into the soil at a depth of 44-50 mm. The seed drills were run in a static position, using the tracer to simulate the seed dressing. The tracer was introduced in the fan air inlet at a rate of 3 g min^{-1} for 10 minutes by means of a volumetric powder feeder (BHT® BD20) with the axial fan activated. The experiment was replicated placing the sowing machine in both forward directions: position A – machine with fan outlet upwind – and position B – machine with fan outlet downwind because each seed drill model tested was equipped with a different fan design (outlet air direction, flow rate intensity, fan position…) (Fig. 1).

The amount of tracer deposited on each Petri dish was determined in laboratory by spectrophotometry analysis. Contaminated samplers were washed with 50 ml of deionised water and washings were then analysed with a spectrophotometer (Biochrom Lybra S11) set up at a wavelength of 434 nm, corresponding to the peak of absorption of the dye. The absorbance value read on the instrument enabled the corresponding amount of tracer to be calculated.

In order to verify the applicability of the methodology proposed, the uniformity of the artificial air stream in the tunnel and the repeatability of measurements of tracer deposits were assessed. The air velocity was measured with a professional anemometer (Allemano Testo 400) that was mounted on a rigid support. Instrument accuracy was ± 0.2 m s^{-1} and data were acquired at 1 Hz frequency. The measuring points were determined by drawing a 0.5 x 0.5 m grid in the transversal section of the tunnel at a distance of 20 m from the axial fan (close to the position of the sowing machine). At each point, the air velocity was determined on the basis of the arithmetical average value of 30 seconds of acquisition. The repeatability of the measurements of tracer deposits on Petri dishes was evaluated by determining the coefficient of variation (CV) calculated on 3 replicates for each collector position.

In order to estimate the global balance between the amount of tracer introduced in the fan of the sowing machine and the amount collected out of the seeder, a specific test was made using a conventional pneumatic seeder (Gaspardo Marta).

Collectors made of cellulose material (Camfil CM360), 200 x 100 mm size, were placed in five different sampling areas: 1) on the frame of the machine, 2) on the ground underneath the seeders, 3) on the ground at downwind distances of 1, 3, 5, 10, 15 and 20 m from the machine, 4) on the tunnel walls and 5) on a grid located at the exit of the tunnel. The amount of tracer deposited on each collector was determined in laboratory by spectrophotometry analysis as described above. To estimate the total amount of tracer deposited in each sampling area, the average collector deposit was projected over the corresponding total surface.

We have separated the results value obtained in the area from 1 to 20 meters (as specified in European Standard ISO 22866) from those obtained in the 5-20 m zone (5 meters is the minimum buffer zone request by several European countries) to highlight the differences of the contamination reduction.

2.3. Seeders used

Tests to assess dust drift were made using three pneumatic seeders (1 – 2 – 3), representative of the Italian context (Table 2). Each machine was tested either in its standard configuration or in modified configurations in order to limit the dust dispersion. It was assumed to operate the seeding with a distance of 0.75 m between the maize rows and to apply 75,000 seeds per hectare. Seeder 1 was tested in its standard configuration and in a modified one where the air was conveyed between the wheels of each seeding element. The second sowing machine was tested, in addition to the standard one, in two further configurations aimed at reducing the dust dispersion: one featured the presence of four 100 mm diameter air hoses conveying the air towards the soil, the second was equipped with one 55 mm diameter air hose for each seeding element, conveying the air close to the share of the seeding furrow. Seeder 3 was tested in its standard configuration and in a modified one where the fan air outlet was conveyed towards the soil by two hoses of 125 mm diameter.

3. Results

3.1. Methodology setup

Air stream velocities measured inside the tunnel at 20 meters downwind distance from the axial fan ranged between 2.8 m s^{-1} (close to tunnel walls) and 3.3 m s^{-1} (central area of the tunnel) (Table 3). The coefficient of variation (CV) of 3 replicates for each measurement point was always below 8%

while the CV referred to the average air velocity obtained in the whole sampling area was 2%.

The global balance calculated between the amount of tracer introduced in the sowing machine and that collected outside the seeder highlighted that applying the proposed methodology it is possible to collect more than 95% of the tracer expulsed from the seeder. A value of 67% (from 55 to 79%) of the tracer deposit was detected under the seeder, 8% (from 6 to 10%) was found on the frame of the sowing machine, 15% (from 10 to 20%) was collected on the tunnel ground downwind from the seeder position, 2% (from 1 to 3%) was retained by the tunnel walls and 3% (from 2 to 4%) was detected at tunnel exit.

3.2. Dust material outflow trials

Seeder 3 in its standard configuration, with the fan outlet oriented upwards, highlighted a tracer deposit value increasing with distance from the machine for up to 15 m, independent of its position (A or B) with respect to air stream.

The use of the air conveyor device reduced the drift effect by more than 50% (Fig. 2). This reduction value reached 85% if only the area between 5 and 20 meters downwind the machine was considered (Table 4).

A similar trend of tracer deposit values increasing with the distance from the machine was obtained also with sowing machine 1 in its standard configuration, while an opposite trend of the tracer deposit values was obtained equipping seeder 1 with the air conveyor device (Fig. 3). Furthermore, the experimental results indicated that the amount of dust (tracer) that drifted away from the seeder was strictly related to the air outlet position. When the modified configurations of the machines were used, it was possible to reduce the total amount of dust drift by 35% when the fan air outlet was oriented against the wind direction, and by about 50% when the fan air outlet was oriented in the same direction as the wind. These reductions were higher (by 43% and 75% respectively) if only the area between 5 and 20 meters downwind the machine was taken into account (Table 5). Data collected with seeder 2, in its traditional configuration, gave a lower drift effect than the other models tested, because this seeder model was already originally equipped with a fan outlet oriented downwards. For this seed drill model, best results, in terms of dust drift reduction, were obtained with the use of the air conveyor device in the seeding elements which allowed a dust drift reduction of about 50-60% (Fig. 4). While conveying the air towards the soil the material deposits were not reduced with respect to the original machine set up (Table 6).

Therefore, using a modified seeder, it was increased the reduction in material dispersion from about 30% (seeder 1) to about 70% (seeder 3). These values increased to 60% and 85% respectively, if only the area between 5 and 20 m downwind of the machine was considered (Table 7).

4. Discussion

At present, seeder dust drift evaluation is generally made in an open environment following the ISO 22866 standard. This standard methodology requires high labor and analysis costs and is not easily applicable because of the restricted environmental conditions required. The new methodology set up at DISAFA, University of Torino is easier to apply and can be used in every environmental condition (all the year round), shows a good repeatability of the tests and requires limited operative times and costs.

However, this proposed method has some limitations: 1) it can be applied to seeder machines only in static conditions; 2) during the tests no seeding operation is made; 3) it can be used only for comparative measurements providing relative dust dispersion values and not absolute ones. Furthermore, on the basis of the experience made in the trials done, it would be necessary to increase the length of the tunnel (only artificial collectors area) in order to collect all the potential dust drift.

The research showed that using appropriate air conveyor equipment on pneumatic seeders, independent of their design, it is possible to reduce by more than 60% the amount of dust drift with respect to conventional sowing machines having the fan outlet oriented upwards (worst case considered as reference – seeder 3). The drift is reduced by more than 70% if only the area between 5 and 20 meters downwind of the machine is considered (Figures 5 and 6). These values are in line with the ones obtained in another work carried out by the DISAFA, University of Turin concerning the sowing machines performances evaluation (Balsari et al., 2010). In this latter study, it was shown that the use of devices enabling the conveyance of the air towards the soil, thanks to the limitation of the size of the fan air outlet, enabled the size of the ground area contaminated with dust to be contained by 80%.

The test method proposed by DiSAFA provided similar results with respect to those obtained applying the ISO 22866 methodology (Rautmann et al., 2009). The comparison of data obtained applying the two different methods was possible only for seeder 3, because this was the only seeder model which was tested with both methods (Fig. 7)

In conclusion, the methodology set up in this study demonstrated its capability to assess the potential dust dispersion from pneumatic seeders and to enhance the effect of the different machine and configurations on the amount of dust drift generated. It could therefore be used in the future for classification of seeders according to drift risks. The use of appropriate equipment (e.g. *ad hoc* air conveyor kit) to contain dust drift effect reduced the toxic substance dispersion on the ground downwind of the machine's position.

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ISO 22866: 2005 Equipment for crop protection - Methods for field measurement of spray drift

Figure captions

Fig. 1 - Scheme of the equipment disposition in the tunnel during the test

Fig. 2 - Amount of drift material of the seeder 3 at different distances

Fig. 3 - Amount of drift material of the seeder 1 at different distances

Fig. 4 - Amount of drift material of the seeder 2 at different distances

Fig. 5 - Drift effect reduction (until 20 meter from the machine) respect to a conventional machine (with upwards air direction).

Fig. 6 - Drift effect reduction (from 5 and 20 meters from the machine) respect to a conventional machine (with upwards air direction).

Fig. 7 - The comparison of data obtained applying the two different methods (DISAFA and JKI)

Figures

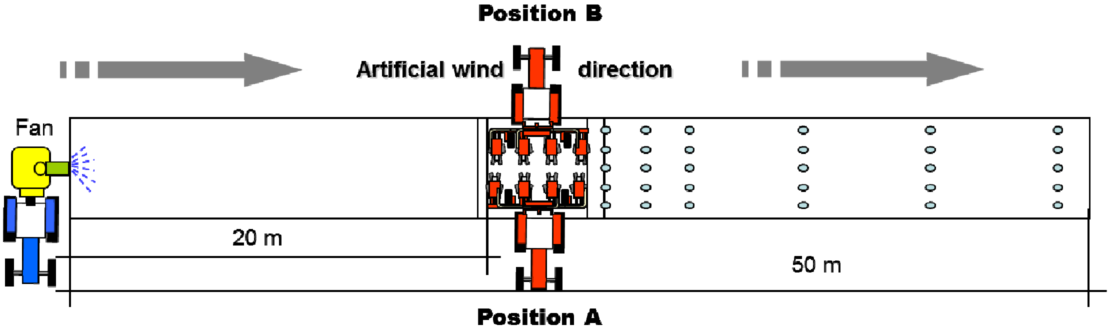
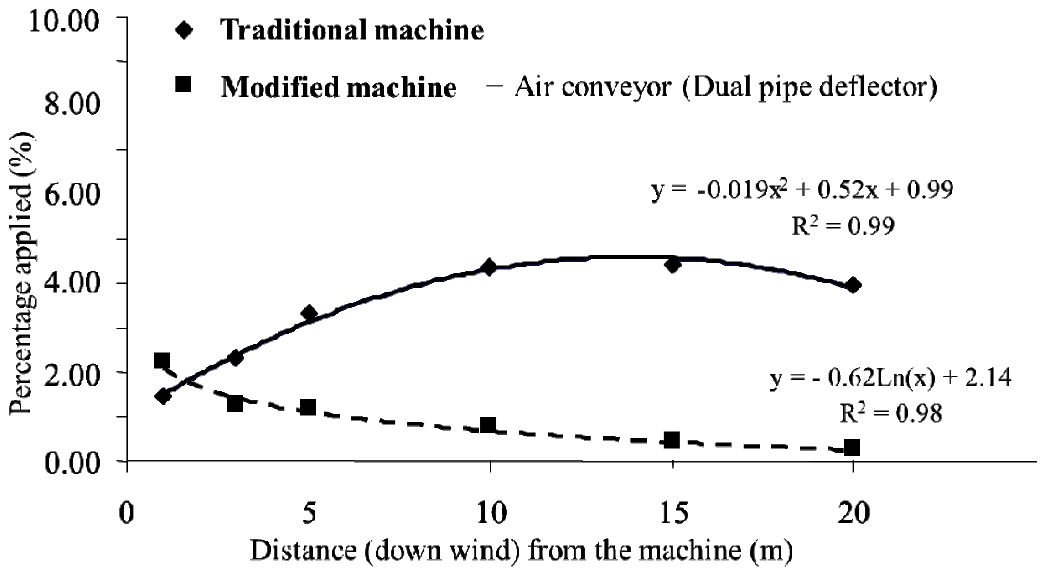


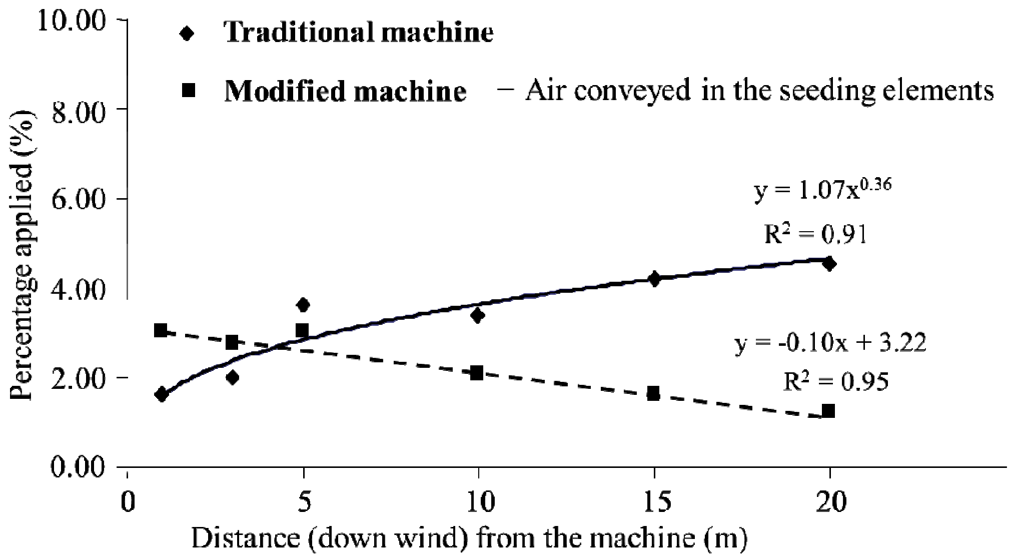
Figure 1

Note for the editor: to be rendered in Black and White



Distance (m)	*1*	*3*	*5*	*10*	*15*	*20*
Traditional (dev.st)	0.03	0.05	0.06	0.09	0.10	0.06
Modified (dev.st)	0.03	0.04	0.04	0.05	0.07	0.07

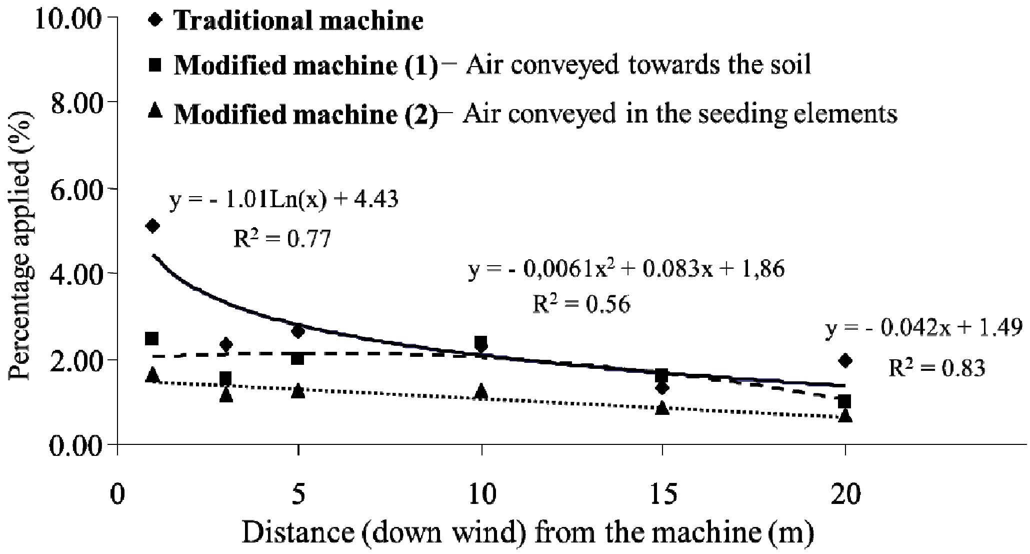
Figure 2



Distance (m)	*1*	*3*	*5*	*10*	*15*	*20*
Traditional (dev.st)	0.06	0.07	0.06	0.04	0.06	0.04
Modified (dev.st)	0.09	0.05	0.09	0.07	0.04	0.05

Figure 3

1



Distance (m)	*1*	*3*	*5*	*10*	*15*	*20*
Traditional (dev.st)	0.08	0.05	0.10	0.06	0.11	0.09
Modified 2 (dev.st)	0.06	0.07	0.06	0.06	0.04	0.03
Modified 1 (dev.st)	0.07	0.09	0.10	0.04	0.03	0.06

2 Figure 4

3

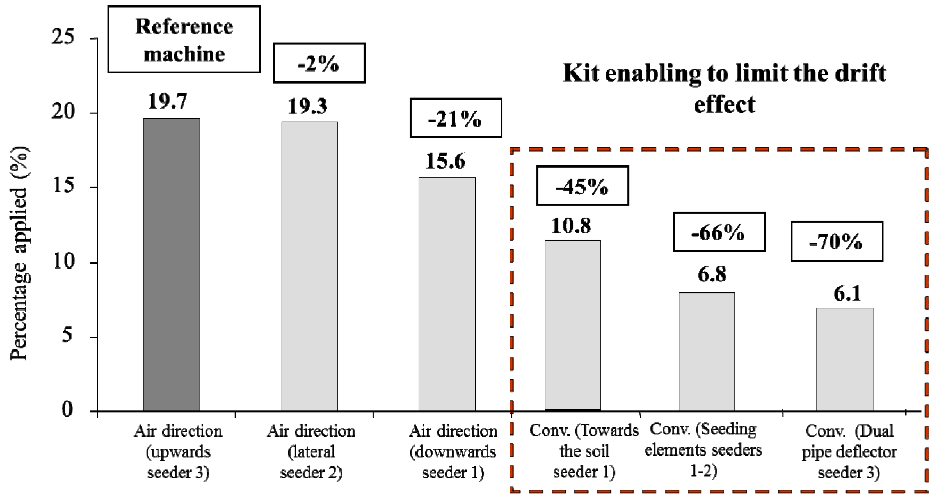


Figure 5

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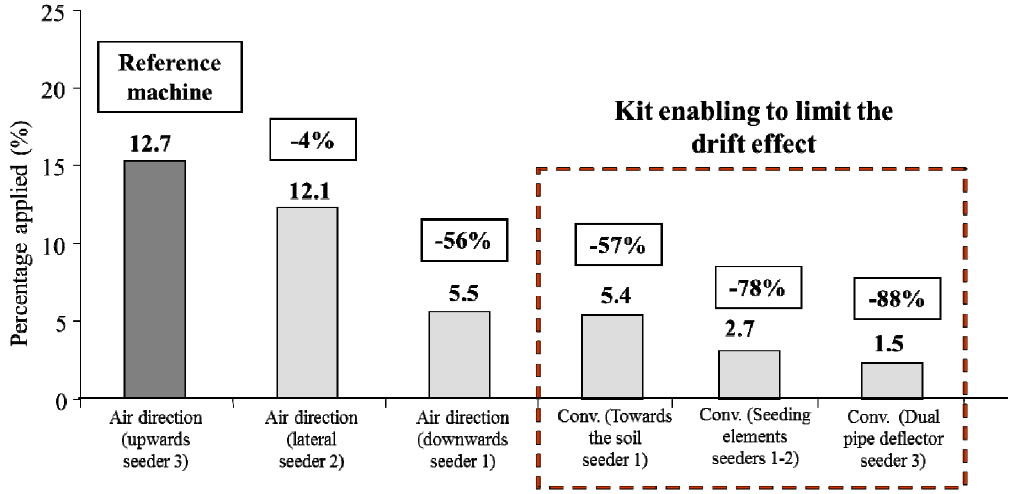

Figure 6

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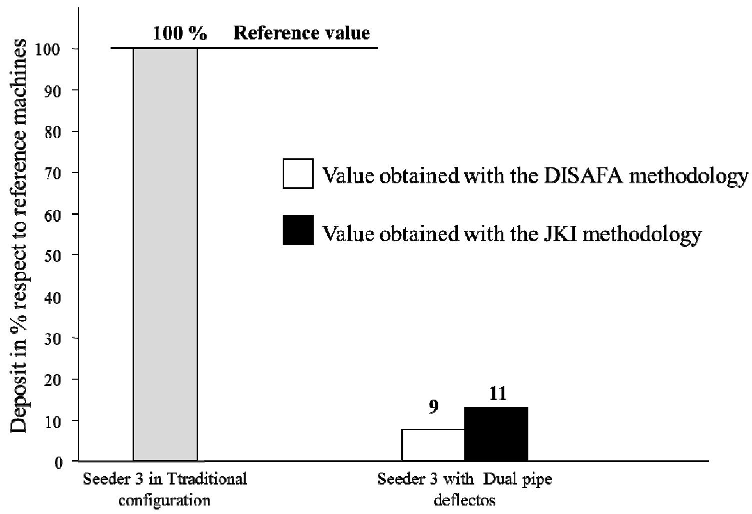
100 %
Reference value
Deposit in % respect to reference machines
100
90
80
70
60
50
40
30
20
10
0
Value obtained with the DISAFA methodology
Value obtained with the JKI methodology
9
11
Seeder 3 in Ttraditional configuration
Seeder 3 with Dual pipe deflectos

Figure 7

Tables

Table 1 – Physical characteristics of the dust dressed seed and tracer Tartrazine E104

Size particles	Dressed seed	Tartrazine E102
D_{10} (µm)	34.1	42.6
D_{50} (µm)	84.1	80.1
D_{90} (µm)	180.9	172.3
Density (g cm^{-3})	0.41	0.44

Table 2 - Main technical features of the fans present on the pneumatic seeders tested

Manufacturer	1	2	3
Seeding elements (n°)	6	6	6
Fan diameter (mm)	440	410	420
Fan width (mm)	45	60	80
Blades (n°)	10	10	8
Blade inclination (°)	30	31	0
Blade width (mm)	30	30	45
Air outlet size (mm)	105 x 45	230 x 60	135 x 80
Air direction	lateral	downwards	Upwards
Fan rotation speed (rev min^{-1})	5,000	5,400	4,500
Air velocity (m s^{-1})	3.2	2.2	4.4
Air flow rate (m^3 h^{-1})	240	210	210

Table 3 - Air velocity value in each point measurement on section tunnel

Tunnel height (m)	*Tunnel width (m)*										
	0	*0.5*	*1.0*	*1.5*	*2.0*	*2.5*	*3.0*	*3.5*	*4.0*	*4.5*	*5.0*
3.0	-	-	-	-	-	2.9	-	-	-	-	-
2.5	-	-	-	2.9	2.9	3.0	2.9	2.9	-	-	-
2.0	-	2.8	3.0	2.9	3.1	3.1	3.1	3.0	2.9	2.8	-
1.5	2.8	2.9	3.1	3.0	3.2	3.2	3.3	3.2	3.0	2.9	2.8
1.0	2.9	3.0	3.0	3.1	3.1	3.3	3.1	3.0	3.0	3.0	2.9
0.5	2.9	3.0	3.0	2.9	2.9	3.0	2.9	2.9	2.9	3.0	2.8
0	2.8	2.8	2.9	2.9	2.8	2.8	2.8	2.8	2.9	2.8	2.8

Table 4 - Reduction of drift material split in two zones with the seeder 3

	Area considered	Percentage applied %)		Reduction (%)
		Trad. Machine	Mod. Machine	
Seed drill in position A (Outlet fan up wind)	Total	12.72	6.29	50
	Until 5 m	3.03	4.78	+ 37
	5-20 m	9.69	1.52	84
Seed drill in position B (Outlet fan down wind)	Total	11.50	5.90	48
	Until 5 m	0.97	4.40	+ 78
	5-20 m	10.53	1.50	85

Table 5 - Reduction of drift material registered with the seeder 1

	Area considered	Percentage applied (%)		Reduction (%)
		Trad. Machine	Mod. Machine	
Seed drill in position A (Outlet air fan upwind)	Total	18.96	14.48	24
	Until 5 m	7.06	7.76	+ 9
	5-20 m	11.90	6.72	43
Seed drill in position B (Outlet air fan downwind)	Total	19.77	13.03	48
	Until 5 m	7.37	9.92	+ 25
	5-20 m	12.40	3.11	75

Table 6 - Amount of tracer (expressed as percentage of the application) collected in different areas of the wind tunnel and operating with the seeder in two position (A – B).

	Area considered	Percentage applied %)			Reduction (%)
		Trad. Machine	Mod. (1) Machine	Mod. (2) Machine	
Seed drill in position A (Outlet fan upwind)	Total	18.94	11.73	7.44	38-60
	Until 5 m	12.19	5.90	4.70	51-61
	5-20 m	6.75	5.83	2.74	14-60
Seed drill in position B (Outlet fan downwind)	Total	12.33	10.02	6.15	18-50
	Until 5 m	7.98	5.98	3.43	25-57
	5-20 m	4.36	4.00	2.72	8-43

Table 7 - Reduction registered for every machines with its device for drift effect mitigation

	Seeder	Traditional seeder	Modify seeder.	Reduction (%)
	A	19.37	13.76	28
Total deposit	B	15.64	6.79	56
	C	19.77	6.10	69
Only deposit in the zone	A	12.15	4.92	60
closed from 5 and 20 meter of	B	10.08	4.06	60
the machines	C	10.11	1.51	85